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China's energy consumption in the building sector: A Statistical Yearbook-Energy Balance Sheet based splitting method

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ABSTRACT

China's energy consumption in the building sector (BEC) is not counted as a separate type of energy consumption, but divided and mixed in other sectors in China's statistical system. This led to the lack of historical data on China's BEC. Moreover, previous researches' shortages such as unsystematic research on BEC, various estimation methods with complex calculation process, and difficulties in data acquisition resulted in "heterogeneous" of current BEC in China. Aiming to these deficiencies, this study proposes a set of China building energy consumption calculation method (CBECM) by splitting out the building related energy consumption mixed in other sectors in the composition of *China Statistical Yearbook-Energy Balance Sheet*. Then, China's BEC from 2000 to 2014 are estimated using CBECM and compared with other studies. Results show that, from 2000 to 2014, China's BEC increased 1.7 times, rising from 301 to 814 million tons of standard coal consumed, with the BEC percentage of total energy consumption stayed relatively stable between 17.7% and 20.3%. By comparison, we find that our results are reliable and the CBECM has the following advantages over other methods: data source is authoritative, calculation process is concise, and it is easy to obtain time series data on BEC etc. The CBECM is particularly suitable for the provincial government to calculate the local BEC, even in the circumstance with statistical yearbook available only.

1. Introduction

The awareness of the worldwide climate change effects, energy shortage, and increasing greenhouse gas emissions have raised people's concern about the current trends in energy consumption (Mi et al., 2015; Zhang et al., 2016). After more than 30 years of rapid economic development, China has become the world largest CO2 emitter with its increasing energy consumption (IPCC, 2014). From 1978 to 2015, China's primary energy consumption grew at an average annual rate of 5.6%, 2.9 times that of the world over the same period (Reinventing fire China, 2016). Thus, China faces the serious challenges on mitigating energy consumption and addressing climate change.

In the context of energy conservation, the building sector has attracted increasingly worldwide attention, as building sector consumed 32% of the world's energy in 2010 (IPCC, 2014) and the percentage of building energy consumption (BEC) is around 40% in many developed countries (IEA, 2016; Ürge-Vorsatz et al., 2012). With the further development of urbanization, issues on energy and emission reduction in buildings will become more prominent in China since the building sector is a major energy consumer (Cai et al., 2009; Liu et al., 2017; Mi et al., 2017; Zhang and Peng, 2017). To curb the energy consumption, China's 13th Five-Year Plan (FYP) (2016–2020) first proposed the cap control target of energy consumption. After that, the Ministry of Housing and Urban-Rural Development (MOHURD)'s 13th FYP for building energy efficiency and green building development proposed a mitigation action plan of improving urban residential energy performance 20% by the year of 2020 based on the 2015 level. Obviously, obtaining accurate and objective BEC data is the premise to carry out cap control and BEC baseline setting. In addition to that, China reported that the building sector would contribute 50% energy saving to reach its

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Notes for the abbreviations

BEC	Building energy consumption/Energy consumption in the building sector
BEE	Building energy efficiency
CBECM	China's building energy consumption calculation method
MOHURD	The Ministry of Housing and Urban-Rural Development of China
FYP	Five-Year Plan
IEA	International Energy Agency
ERI	Energy Research Institute
PNNL	Pacific Northwest National Laboratory
TU-BERC	Tsinghua University-Building Energy Research Center
CBEM	China building energy model
LEAP	Long-range Energy Alternatives Planning

carbon emission peak goals ahead of time (Reinventing fire China, 2016). Therefore, the basic data of BEC also plays a fundamental role in predicting carbon emission peak value.

Previous scholars conducted numerous researches on BEC, but they had different interpretations on BEC, such as embodied energy, energy consumption in construction industry, energy consumption in building sector, life cycle building energy consumption etc. And they referred to inconsistent statistical scopes for the total energy consumption and different conversion methods of electricity etc. Actually, energy consumption in China's building sector is not counted as a separate type of energy consumption, but divided and mixed in other energy sectors in the composition of *China Statistical Yearbook* (Cai, 2011; Yuan et al., 2017). More importantly, the lack of a unified calculation method and inconsistent data source for BEC are critical obstacles to obtain authoritative and high recognized BEC data (Cai, 2011; Cai et al., 2009). Such shortcomings resulted in the "heterogeneous" of current BEC in China, which is shown[1] in Fig. 1. Therefore, energy consumption data with high degree of recognition in China's building sector, as well as its ratio, remain unavailable now, which hinder the BEE work, energy plan and policy evaluation for the government.

For this purpose, this study attempts to fill these gaps and the main objectives are as follows: (1) It proposes a set of general China BEC calculation method (CBECM) based on *China Statistical Yearbook-Energy Balance Sheet*. (2) It estimates China's BEC from 2000 to 2014 with CBECM, and the results with high degree of recognition are derived. (3) The results are compared with those from other studies like Tsinghua University-Building Energy Research Center (TU-BERC), International Energy Agency (IEA), Energy Research Institute (ERI), Pacific Northwest National Laboratory (PNNL) and China Ministry of Housing and Urban-Rural Department (MOHURD). The CBECM proposed in this study can ensure the authoritative and uniform data source when estimating BEC. Besides, the CBECM can provide a very concise and practical way of obtaining consistent and reliable data regarding China's BEC

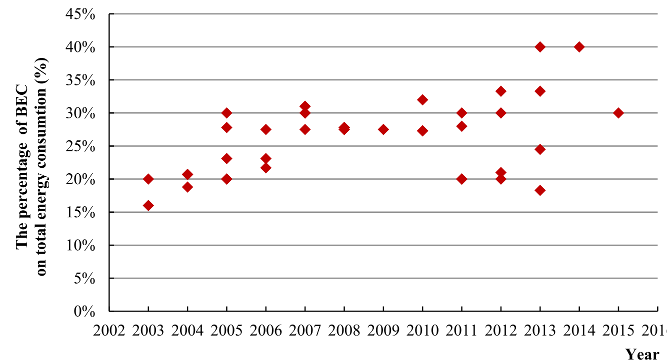

Fig. 1. China BEC percentage data.

through splitting out statistical yearbook data for government and local officials even if they have no statistical training in Chinese conditions. It can facilitate the building energy efficiency (BEE) policy design and policy impact evaluation for the government. It is also of significance to set BEC baseline and analyze carbon emission peak for the government. The CBECM can also be used to calibrate the statistical data at the provincial level reported by the MOHURD.

The reminder of this study is presented as follows. Section 2 presents the literature review. Section 3 proposes the methodology, and in Section 4 calculation results of China's BEC data are presented and compared with other studies. Finally, in Section 5 conclusions and policy implications are provided.

2. Literature review

2.1. Different interpretations and scopes of building energy consumption

Regarding BEC, there are different interpretations in the academia, such as embodied energy in construction industry, building energy consumption, energy consumption in construction industry, energy consumption in construction filed, and life cycle building energy consumption. The embodied energy consumption refers to the energy consumption in the building material production and building construction stage (Basbagill et al., 2013; Hamilton-MacLaren et al., 2009; Hong et al., 2016). The energy consumption in construction industry means the energy use in building construction stage and demolition stage. Energy consumption in construction filed means the sum of operation energy consumption and energy consumption in construction industry. Building energy consumption (i.e., energy consumption in building sector) refers to the energy consumption in building operation stage (Cai, 2011, 2014; IEA, 2016; McNeil et al., 2016; Zhang et al., 2015; Zhou et al., 2007; Zhou and Lin, 2008). Life cycle building energy consumption means the total energy consumption in the whole life cycle of buildings including energy used in building material production, building construction, building operation, and building demolition stage (Ma et al., 2017; Sartori et al., 2016).

Among all of the above mentioned interpretations about BEC, only energy consumption in construction sector (industry) is listed in the composition of energy consumption in *China Statistical Yearbook*. This is the root cause of the lack of energy consumption data in China's building sector. In fact, building energy consumption is divided and mixed in other energy sectors listed in *China Statistical Yearbook*. This is why we propose a method to try to split out the buildings related energy consumption mixed in other sectors.

[1] **Sources: 2003 data**(Long, 2005; Zhu, 2005), **2004 data**(Cai et al., 2009; Yang and Jiang, 2007), **2005 data**(IEA, 2007; Long, 2005; Zhou and Lin, 2008), **2006 data**(Jiang and Yang, 2006; Lin et al., 2009b; Wang, 2009; Yang, 2009), **2007 data**(IEA, 2007; Li and Yao, 2009; Xia et al., 2014; Yang and Jiang, 2007), **2008 data**(He et al., 2014; Kong et al., 2012; Zhang et al., 2008), **2009 data**(Wu and Long, 2009), **2010 data**(Cao et al., 2017; IEA, 2013, 2012), **2011 data**(Du et al., 2014; Xia et al., 2014), **2012 data**(MOHURD, 2011; Peng et al., 2015), **2013 data**(Peng et al., 2015; Wang and Sun, 2013), **2014 data**(Xia et al., 2014), **2015 data**(Ma et al., 2015).

In addition to different interpretations, there are two forms of energy previous scholars commonly used to estimate BEC ratio: primary energy consumption (Cai, 2014; Cai et al., 2009; Zhou et al., 2007) and final energy consumption (ERI, 2003; IEA, 2016; Richarad et al., 2005; Yu et al., 2014b). The inconsistent statistical scopes of total energy consumption are also an important factors leading to varied BEC ratios.

2.2. Different estimation methods and data sources of building energy consumption

As for the estimation of BEC, there are three categories of methods previous scholars used: macro statistic data based method, comprehensive energy intensity based method and modeling method. In general, the chosen model is of significance to the accuracy of the results and operability for estimating of building energy consumption.

The basic idea of the macro statistic data based method is to split out the energy consumption associated with buildings from total energy consumption in statistics and then sum them together. For example, Wang proposed an adjustment method for statistical data on China's energy consumption (Wang, 2006, 2007) to estimate China's BEC. The TU-BERC divided China's BEC into three categories: commercial BEC, residential BEC and heating energy consumption in northern urban areas (Center, 2008). And their processing methods included: (1) deducting oil consumption from household energy consumption, wholesale and retail trades, hotels and catering services, and other sectors; and (2) calculating heating energy consumption separately. Long (2005) used energy end-use consumption statistics to estimate BEC by removing transportation, storage, tertiary industry and household energy consumption (Long, 2005). There are other representative scholars (Lin et al., 2009a; b; Zhang et al., 2008; Zhao et al., 2017). However, in this kind of method, none considered the building related energy consumption contained in other sectors,[2] such as industrial and construction sector, and heating energy consumption that should be corrected. As for the IEA's calculation for China BEC, they just calculated the BEC according to their principles referencing *China Statistical Yearbook*. The specific calculation method is not published and the IEA's balance sheets are widely vary to China's energy balance sheets.

Moreover, other researchers also adopted the comprehensive energy intensity method to estimate BEC. The idea of this method is to investigate and obtain the energy intensity of each type of building according to its energy consumption characteristics and the floor area. The total energy consumption related to buildings can then be calculated accordingly (Abrahamse et al., 2005; Jiang and Yang, 2006; Long, 2005). Different countries have different energy statistical systems, but—whether it is by international organizations such as the IEA or major developed countries such as Europe, the United States and Japan—national energy consumption statistics are commonly classified according to the following four sectors: industry, transportation, and commercial and residential (household) buildings sectors. Using macroeconomics for total national floor space in commercial buildings and total number of households in residential buildings, all commercial and residential BEC can then be calculated (Energy Information Administration, 2012a, 2012b). Ming-Tsun Ke et al. (2013) calculated United States BEC using a software simulation and found that accurately configuring parameters was important for obtaining accurate BEC calculation result (Ke et al., 2013). Looking at China's BEC, Tu led the “China Building Energy Economy and Technology Policy Research” group in the first effort to conduct a comprehensive survey of various building types covering China's northern heating areas and along the Yangtze River (Tu, 1991). Chen et al. conducted research on statistical methods for determining commercial BEC, identifying methods for maintaining a consistent calibration of data, and processing the availability of interference data and abnormal changes in indicators (Chen et al., 2008a). Chen et al. set up a four-layer structure index system for residential BEC statistics, including: residential building profiles, household basic information, ownership of energy consumption equipment and usage, the energy consumption of various centralized system equipment, and household electric consumption and other types of energy consumption (Chen et al., 2008b). Wu and Long (2009) used the energy intensity method to calculate China BEC in 2005 and calculated the percentage of BEC in China as 27.5% of total energy consumption (Wu and Long, 2009). The Promotion Center for Science and Technology of MOHURD measured China's BEC in 2011, using the energy intensity method and data obtained from the “energy consumption and energy saving information for civil building statistical reporting system.” (Cai, 2011). This method is different from the macro statistic data based method in data source and it also requires large volume of data.

Besides, a bunch of other scholars used the BEC modeling method to estimate BEC. This kind of method relies on the input data, which can be used to calculate or simulate the energy consumption. According to the different levels of details of the available input data, the modeling method includes two kinds of models: the top-down and the bottom-up model. The top-down approach primarily focuses on the inter-relationship between the energy sector and macro economy, and it cannot distinguish the individual end-uses energy consumption (Swan and Ugursal, 2009). Based on the aggregated macro historical data of the macroeconomic variables, the BEC of a certain country or region can be calculated or predicted with the top-down approach. The most well-known prediction tool is the demand module of the National Energy Modeling System (NEMS) (Swan and Ugursal, 2009). PNNL's method contains macro driving forces such as GDP, population etc., and micro individual end-use service energy demand. Other representative top-down models are: MARKAL (Fishbone and Abilock, 1981), TIMES (Merkel et al., 2017), AIM (Matsuoka et al., 1995) and Global Change Assessment Model (GCAM) (Yu et al., 2014a). On the contrary, the bottom-up approach concentrates on disaggregated components. The national or regional energy consumption can be obtained by extrapolating based on the representative weight of the modeled sample buildings. Enormous and detailed micro-level survey data and information are included in this model (Kavgic et al., 2010; Swan and Ugursal, 2009). This approach can be grouped into the statistical method and the engineering method. The statistical method depends on historical information and regression relationship among the individual end-uses. The engineering method is based on end-uses' engineering characteristics, such as power ratings and heat transfer relationship etc. Representative bottom-up models are: LEAP model (Zhou, 2011), CBEM model (Yang, 2009), Energy for Buildings (EFB) model (Delmastro et al., 2015) and other models. In ERI's method, the building sector is categorized into residential and commercial building, and these buildings are then sub-categorized into individual end-uses. The total BEC can be obtained by summing up the

[2] The end-use energy consumption listed in *China energy balance sheets* are distributed into seven sectors: (1) Agriculture, forestry, animal husbandry, fishery and water conservancy; (2) Industry; (3) construction; (4) Transport, storage and post; (5) Wholesale and retail trades, hotels and catering services; (6) Other sectors; and (7) Household consumption. Energy consumption in Wholesale sector and Other sectors are related to buildings excluding the private transport energy consumption, which is mainly oil consumption, contained in these sectors. The energy consumption composition and the deficiencies will be analyzed in detail in Section 3.

individual end-use energy consumption from bottom to up (ERI, 2003; Zhou et al., 2003). And there are other bottom-up models (Yang et al., 2017). The advantages and disadvantages of these three kinds of BEC estimation methods are listed in Table 1.

To sum up, there are some gaps for the extant research. First, the definitions, statistical scopes and data sources of BEC are inconsistent in the current estimation of China's BEC. Second, in macro statistic data based method, none considered energy consumption associated with buildings mixed in other sectors in the composition of *China Statistical Yearbook*, such as energy consumption in industrial and construction sectors, and the heating energy consumption that should be corrected. This would lead to the underestimation of China's BEC. The building related energy consumption mixed in other sectors in *Statistical Yearbook* need to be adjusted to align with international standards. Third, as for the comprehensive energy intensity based method, it needs to carry out a wide range of BEC statistics and investigations, and the uniqueness of the data source and validity of the sample cannot be ensured. Fourth, regarding the modeling method, it has large variable assumptions and data requirements, and it is hard to obtain some related data; the results need to calibrate against with the *Statistical Yearbook*. The reliability of the data and result cannot be ensured. Overall, there is no consistent interpretations, statistical scopes, data source and conversion method of electricity. More importantly, a set of unified and concise calculation method for BEC is lacking and pervious methods have deficiencies in varied degrees, and thus data on China's energy consumption in building sector with high degree of recognition remains unavailable now.

Therefore, this paper tries to fill these gaps and the contributions of this study mainly includes the following aspects. Specifically, (1) this study proposes a set of more universal calculation method for BEC in China: *Statistical Yearbook-Energy balance sheet* based China's BEC calculation method (CBECM). The proposed method can overcome previous studies' inconsistent definitions of the BEC, inconsistent total energy consumption, inconsistent conversion of electricity and complex assumptions etc. It can provide a very concise way of obtaining consistent China's BEC through splitting out the building related energy consumption from the energy consumption listed in the composition of *Statistical Yearbook* for government and local officials even if they have no statistical training in Chinese conditions. (2) This study calculates China's BEC by type from 2000 to 2014 using CBECM, which can provide reliable and valuable data evidence for the governmental officials in terms of building energy efficiency, policy planning or energy policy evaluation in the building sector. (3) The CBECM and the results of this study are compared with other studies like TUBERC, IEA, ERI, PNNL and China MOHURD. The CBECM is superior to other methods in the following aspects: data source is authoritative, data collection is convenient with easy-to-obtain time series data on BEC, calculation method is general and calculation process is concise etc. The results of CBECM has high degree of recognition and the CBECM can be used to calibrate the statistical data at the provincial level reported by the MOHURD.

3. Methodology

3.1. The existing deficiencies in obtaining energy consumption data from China energy balance sheets

The end-use energy consumption sectors in China energy balance sheets are categorized into seven categorizes: ① Agriculture, forestry, animal husbandry, fishery and water conservancy; ② Industry; ③ Construction; ④ Transport, storage and post; ⑤ Wholesale and retail trades, hotels and catering services; ⑥ Other sectors; and ⑦Household consumption. Existing problems when obtaining energy consumption data from China energy balance sheets are as follows.

(1) Building-related energy consumption includes some transport energy consumption

In China energy balance sheets, the main energy consumption data associated with buildings are related to three sectors: ⑤ wholesale and retail trades, hotels and catering services; ⑥ other sectors; and ⑦ household consumption. Private enterprises or private transport energy consumption data for related industries are included as part of this energy consumption data because China's energy consumption is counted by sectors.

(2) Partial energy consumption related with buildings is included in industrial and transport sectors

Energy consumption for the industrial, construction, transport, storage and postal sectors includes partial energy consumption related with buildings, such as railway station energy consumption, bus station energy consumption, terminal energy consumption at airports, post office energy consumption and energy consumption in office buildings in production areas, such as staff dormitories, that have not been independently documented in industrial enterprises.

Table 1
Comparison of different BEC estimation methods.

	Macro statistic data based method	Comprehensive energy intensity based method	BEC modeling method
Advantages	● Data source is authoritative and unique ● Data is open and easy to access ● The calculation is simple	● It is beneficial to compare different types of BEC situation in different regions. ● It can be matched with the civil BEC reporting system.	● The method can be related to the technical level and can be used to analyze the impact of technical factors or policy factors on BEC. ● It facilitates the BEC scenario analysis. ● It facilitates prediction and assessment of building energy efficiency potential or amount of energy savings.
Disadvantages	• The statistical data need to be adjusted in line with international standard	● It needs to carry out extensive BEC statistics and investigation, which will be time-consuming. ● The uniqueness of data source and the validity of the sample cannot be ensured.	● Large data requirements; hard to obtain some data; need to calibrate against with statistical yearbook. ● Subject to capacity development, sample size, statistical methods and other factors; data reliability needs to be improved. ● Cannot obtain a unified, reliable data sources before the civil BEC statistical system get mature.

(3) Building central heating energy consumption counted in the *China Energy Statistical Yearbook* is significantly lower than the actual value

The building central heating energy consumption in China energy balance sheets is significantly lower than the actual value. This is attributed to several causes. First, China's heating metering system is imperfect, so heat consumption cannot be counted like electricity or gas, which is charged fees by household metering. Therefore, the only way to calculate heating energy consumption is by using the energy consumption data of heat-supply enterprises. Second, China's energy statistics are collected primarily for large industrial enterprises, specifically enterprises with income exceeding $20 million or comprehensive energy consumption over 10,000 tons of coal equivalent (tce), which leads to lower heating energy consumption statistics. Third, heating energy consumption at cogeneration facilities is not listed separately, neither is energy consumption at power generation facilities accounted for, resulting in low heating energy consumption statistics.

3.2. China BEC calculation method based on the statistical yearbook (CBECM)

3.2.1. The calculation method for the total BEC

As mentioned in Section 3.1, there are seven end-use consumption sectors in China energy balance sheet. The energy consumption in these seven sectors can be represented as E_A, E_I, E_C, E_T, E_W, E_O and E_H respectively. That is: ①Agriculture, Forestry, Animal Husbandry, Fishery and Water Conservancy (E_A), ② Industry (E_I), ③ Construction (E_C), ④ Transport, Storage and Post (E_T), ⑤ Wholesale and Retail Trades, Hotels and Catering Services (E_W), ⑥ Other Sectors (E_O) and ⑦ Household Consumption (E_H). There are four main steps to calculate the China BEC based on *China Statistical Yearbook*, and they are specified as follows.

Step 1 Calculate the basic amount of the BEC

As mentioned in Section 3.2, the energy consumption in three sectors E_W, E_O and E_H listed in *China energy balance sheets* are mainly associated with buildings. Therefore, the energy consumption in these three kinds of sectors are collectively set as the basic amount of BEC, which can be expressed as

$$E_{basic} = E_W + E_O + E_H \tag{1}$$

where E_{basic} refers to the basic amount of the BEC. E_W represents the energy consumption in wholesale and retail trades, hotels and catering services sector, and E_O and E_H denote energy consumption in other sectors and household consumption respectively.

Step 2 Deduct the transport energy consumption contained in the basic amount of BEC

Referring to Wang's method for the transport energy consumption data contained within the total BEC (Wang, 2007), the processing method of this study is expressed as

$$E_1 = E_W^t + E_O^t + E_H^t \tag{2}$$

where E_1 refers to the sum of the energy consumption used for private enterprises or private transport contained in the wholesale and retail trades, hotels and catering services sector (E_W^t), other sectors (E_O^t) and household consumption (E_H^t), as described in Section 3.1. This is because China's energy consumption is counted by sectors. Private enterprises or private transport energy consumption are mainly counted in gasoline and diesel consumption. E_W^t denotes the private enterprises or private transport energy consumption contained in the wholesale and retail trades, hotels and catering services sector. E_W^t equals to the sum of 95% gasoline consumption and 35% diesel consumption in wholesale and retail trades, hotels and catering services sector. E_O^t represents the private enterprises or private transport energy consumption contained in other sectors. E_O^t equals to the sum of 95% gasoline consumption and 35% diesel consumption in other sectors. E_H^t represents the private transport energy consumption contained in household consumption. E_H^t equals to the sum of 95% gasoline consumption and all the diesel consumption in household consumption.

Step 3 Add the corrected heating energy consumption

In the energy balance sheets, "total urban heat supply quantity" and "central heating" are contained in the "regional urban heating situation" in the *China Statistical Yearbook - Urban Overview*. The northern district China heating energy consumption data can be calculated along with the total heat supply amount. The correction method for building heating energy consumption calculations is as follows:

$$E_2 = E_{Heating} - \left(E_W^{Heat} + E_O^{Heat} + E_H^{Heat}\right) \tag{3}$$

where E_2 refers to the corrected heating energy consumption; $E_{Heating}$ represents the energy consumption of district heating in northern cities and towns. The energy consumption for district heating in northern cities and towns is calculated according to the sheet, "China Central Heating Supply by Region", in the *China Statistical Yearbook*. E_W^{Heat}, E_O^{Heat} and E_H^{Heat} represents the heat consumption contained in "wholesale and retail trades, hotels and catering services," "other sectors" and "household consumption."

Step 4 Add the BEC contained in other remaining sectors

a) Processing method for BEC contained in transport, storage and post sector

Coal consumption in the transportation sector should be categorized as building energy use. The reason is that the steam engine is obsolete in modern society. Coal is no longer being used as fuel power for transportation and trains no longer use coal. Energy consumption in the transportation, storage and postal sector is primarily by transportation stations and post office building heating. Therefore, all the coal consumption should be included in the total BEC.

Electricity consumption in the transportation sector occurs in three primary areas: railways, pipeline transport and urban public transport. First, the primary vehicles used in the railway sector are diesel and electric locomotives. Diesel locomotives mainly use diesel and diesel can generate the driving force. The main source for electric locomotives is electricity, which can be accessed through the power grid. Second, the electric pump is generally used for driving in liquid pipeline transport, while gas pipelines are mainly driven by an electricity-powered compressor. Third, in urban public transport, electric power is mainly used in urban rail transit and buses. In addition to these three areas of electricity use, the remaining electricity use should be designated as building electricity consumption. Therefore, the processing method of BEC in transport, storage and post is as follows:

$$E_3 = E_T^c + E_T^{eb} \tag{4}$$

where E_3 refers to the part of BEC contained in transport, storage and post sector; E_T^c denotes the coal consumption by transport, storage and post sector; E_T^{eb} denotes the building electricity consumption by transport, storage and post sector. $E_T^{eb} = E_T^e - E_T^{et}$. E_T^e represents the total electricity consumption by transport, storage and post sector and E_T^{et} denotes the electricity consumption for transportation in transport, storage and post sector. E_T^{et} contains electricity consumption in electrified railways, electricity consumption in pipelines and electricity consumption in urban public transport.

The electricity consumption of electrified railways, piped transport and in urban public transportation are counted separately in the total social electricity consumption sheet, but these three kinds of electricity do not appear in the *Statistical Yearbook*. According to the statistical data (Wang, 2009, 2007), these three types of electricity consumption in transportation account for around 50% of the electricity consumption of transport, storage and post. In addition, other vehicles consume very little electricity, mainly station, bus station, terminal building and post office electricity consumption. For simple calculation, 40% of the electricity consumption by transport, storage and post is included in BEC (i.e., $E_T^{eb} = 40\% \times E_T^e$).

b) Processing method for BEC contained in the industrial and construction sectors

In industrial and construction sectors, non-production energy consumption is not counted separately in some enterprises. For example, the energy consumption of office buildings and staff dormitories in production areas (commonly found in China's old industrial plants) should be counted as BEC. This particular form of energy consumption is difficult to calculate using the current information available, and so it is not considered in this study. The reasons are as follows (1) this particular energy consumption (i.e., building energy use in these two sectors). is minimal and does not significantly influence the total BEC in this study; (2) BEC is an important performance indicator for production enterprises, so companies have sufficient motivation and enthusiasm to reduce BEC to improve performance; and (3) companies are requested to count BEC independently in the statistical report system. Therefore, most BEC from these two sectors tend to be counted and uncounted consumption will decrease gradually in the future.

In summary, the calculation method for China's total BEC can be expressed as

$$E_B = E_{basic} - E_1 + E_2 + E_3 \tag{5}$$

where E_B denotes the total BEC. The calculation procedure of the CBECM are shown in Fig. 2.

3.2.2. The calculation method for the China BEC by type

1) The formula for estimation of commercial BEC is:

$$E_{CB} = E_W + E_O - \left(E_W^t + E_O^t\right) + E_2 \times r_{CB} + E_T^b \tag{6}$$

where E_{CB}represents commercial BEC, E_W^tandE_O^t represent transport energy consumption contained in$E_W$and E_O(these two parts of energy consumption need to be deleted), r_{CB}represents heat consumption in urban commercial buildings as the percentage of E_2, and E_T^brepresents the BEC included in E_T.

2) The formula for estimation of urban residential BEC is:

$$E_{RB(u)} = E_{H(u)} - E_{H(u)}^t + E_2 \times r_{RB(u)} \tag{7}$$

where$E_{RB(u)}$represents urban residential BEC, $E_{H(u)}$ represents urban household energy consumption, $E_{H(u)}^t$ represents transportation energy consumption which, contained in$E_{H(u)}$ and$r_{RB(u)}$, represents the proportion of urban residential heat consumption of E_2.

3) The formula for estimation of rural residential BEC is:

$$E_{RB(r)} = E_{H(r)} - E_{H(r)}^t \tag{8}$$

where$E_{RB(r)}$represents rural residential BEC$E_{H(r)}$, represents urban household energy consumption, and$E_{H(r)}^t$ represents transportation energy consumption, which is contained in$E_{H(r)}$ and needs to be deleted. Then, the corrected heating energy consumption is apportioned to commercial BEC and urban residential BEC according to the percentage of urban commercial heat consumption and urban residential heat consumption. The BEC contained in the transport, storage and postal sector is attributed to tertiary industry energy consumption, so it should be categorized as commercial BEC.

4. Measurement and analysis on the China BEC with CBECM

4.1. Data source

The raw data in this study are all derived from *China Statistical Yearbook*. The basic amount of BEC data are from *China Energy Statistical Yearbook* and *China Statistical Yearbook*. Some electricity consumption data are derived from the *China Electricity Council*. The latest data from the *China Energy Statistical Yearbook* is available for 2014; the data for 2015 has not yet been published. According to the third economic census, the *China Energy Statistical Yearbook* has adjusted energy consumption data since 2000. Therefore, from the perspective of energy consumption data, the appropriate research scope of this study is 2000–2014.

As for the method of conversion of electric power into a standard coal equivalent, this study used the coal power plant equivalent method. This is because, although the *China Energy Statistical Yearbook* provides energy consumption related data by two methods (i.e., coal power plant equivalent method and calorific value energy method), it only retains the coal power plant equivalent method in *China Statistical Yearbook*. The data released by China's external sources uses the coal power plant equivalent method. Therefore, to maintain comparability with total national energy consumption, this study also uses the coal power plant equivalent method [3] for calculating BEC percentages. That is to say the BEC and the total energy consumption are all primary energy consumption. This study does not consider the biomass energy based on the following two reasons: (1) The biomass energy is not included in China's statistical system and the statistical channel for the biomass energy is lacking. (2) The caliber of the BEC in our study needs to be consistent with China's statistical caliber. If the biomass energy was added into the BEC, it would result in the incomparability between the BEC and the total energy consumption in the whole country.

[3] The coefficient of coal consumption in generating electric power in the calendar years are from China energy balance sheet in the "*China Energy Statistical Yearbook*" over the years.

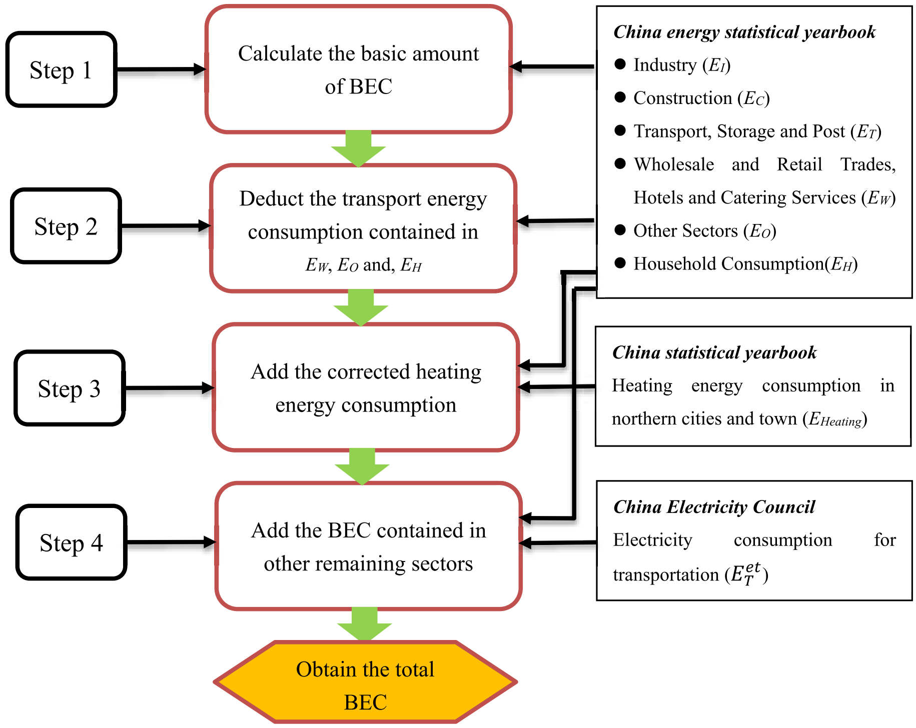

Fig. 2. The calculation procedure of the CBECM.

4.2. Results of China's BEC

According to the CBECM, the total BEC data in China between 2000 and 2014 are calculated using Eq. (1) thru (5). The BEC of each category (i.e., commercial, urban residential and rural residential buildings) are calculated by formulas (6) and (8). The results are shown in Table 2. The percentage of BEC in commercial buildings and residential buildings are calculated using data from the *Statistical Yearbook*.

4.3. Analysis of China's BEC

4.3.1. Analysis of the status quo of China's BEC

The amount of total China BEC, urban residential BEC, commercial BEC and rural BEC calculated by processing data from the *Statistical Yearbook* are shown in Fig. 3. In 2014, China's BEC was approximately 814 million tons of standard coal equivalent (tce) (excluding rural biomass), accounting for 19.1% of total national energy consumption. Of this, urban residential BEC, commercial BEC and rural residential BEC were 301 million tce, 326 million tce and 187 million tce respectively (as shown in Fig. 3).

4.3.2. Analysis on the characteristics of China's BEC

The BEC by type and the percentage of BEC from 2000 to 2014 are shown in Fig. 4. As Fig. 4 shown, the total BEC in China grew continuously between 2000 and 2014. BEC increased 1.7 times, rising from about 301 million tce in 2000 to 814 million tce in 2014 at an average annual increase of 5.6%. The percentage of BEC as part of total energy consumption from 2000 to 2014 remained relatively steady at between 17.7% and 20.3%.

As shown in Fig. 5, BEC in commercial, urban residential and rural residential buildings grew similarly, with the percentages of

Table 2
China's building energy consumption by type (2000–2014) (Unit: 100 million tce).

Year	Urban residential BEC	Rural residential BEC	Commercial BEC	Total BEC	The percentage of BEC
2000	1.31	0.70	1.00	3.01	20.48%
2001	1.19	0.73	1.17	3.09	19.87%
2002	1.35	0.79	1.29	3.43	20.26%
2003	1.51	0.90	1.54	3.96	20.07%
2004	1.67	1.04	1.69	4.41	19.13%
2005	1.85	1.13	1.85	4.84	18.52%
2006	2.01	1.20	1.99	5.20	18.14%
2007	2.19	1.29	2.08	5.56	17.86%
2008	2.27	1.32	2.22	5.82	18.14%
2009	2.36	1.37	2.33	6.06	18.02%
2010	2.43	1.46	2.51	6.39	17.73%
2011	2.53	1.60	2.79	6.92	17.89%
2012	2.68	1.70	3.02	7.40	18.41%
2013	2.88	1.84	3.19	7.91	18.98%
2014	3.01	1.87	3.26	8.14	19.12%

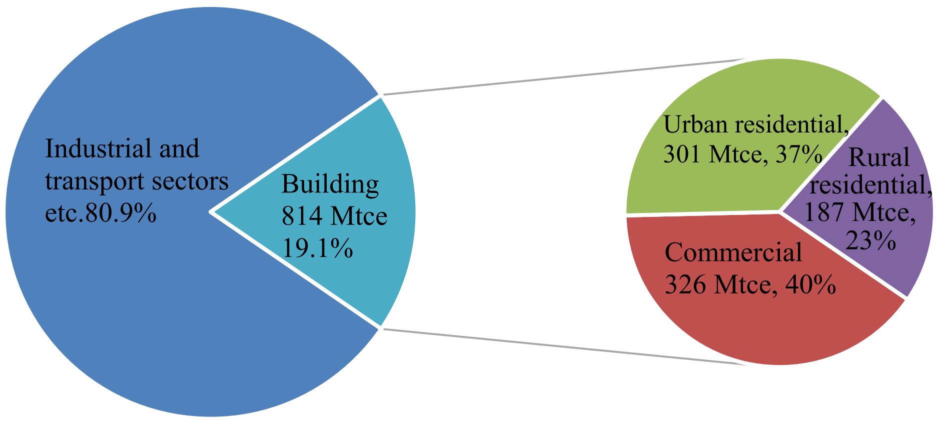

Fig. 3. The breakout of China's building energy consumption in 2014.

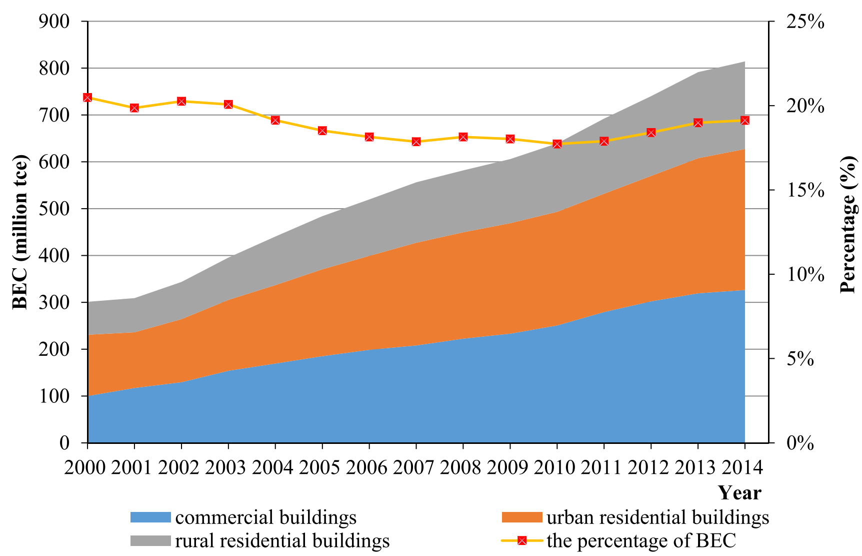

Fig. 4. China's building energy consumption from 2000 to 2014.

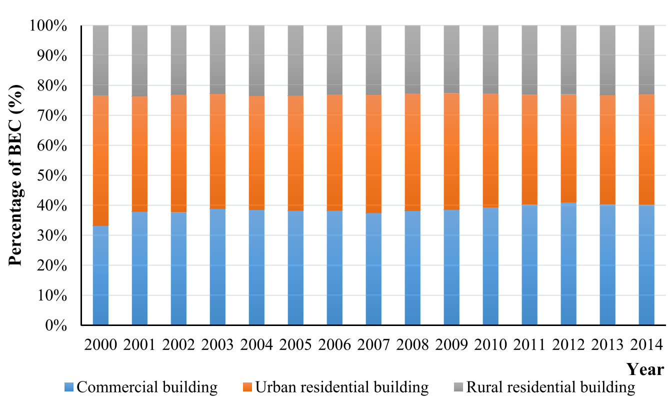

Fig. 5. The proportion of China's BEC by type.

the three energy consumption sectors staying relatively stable. Between 2000 and 2014, the proportion of energy consumption by commercial buildings compared to total BEC was between 33.2% and 40.8%, with figures for urban residential BEC and rural BEC at 36.2%–43.5% and 22.6%–23.6% respectively.

5. Comparison with the results of other studies

5.1. Comparison with the results from TU-BERC, ERI and PNNL

TU-BERC's CBEM model and ERI's method are typical bottom-up end-use energy modeling approach, and PNNL's model is the hybrid model of top-down and bottom-up approach. Take CBEM model for example, which is shown in Fig. 6.

As shown in Fig. 6, there are five modules in the CBEM, comprising the number of building and user module, northern town heating energy, urban residential energy (not including heating in northern China), commercial building energy (not including heating in northern China) and rural residential energy (Yang, 2009). 253 assumptions are needed to calculate the BEC. ERI's method is a bottom-up LEAP model and China's end-use energy consumption is grouped into industry, transportation and building sector. And the building sector is further categorized into residential and commercial building and these buildings are then sub-categorized into individual end-uses. The total BEC can be obtained by summing the individual end-use energy consumption from bottom to up (ERI, 2003; Zhou et al., 2003). PNNL's method contains macro driving forces such as GDP, population etc., and

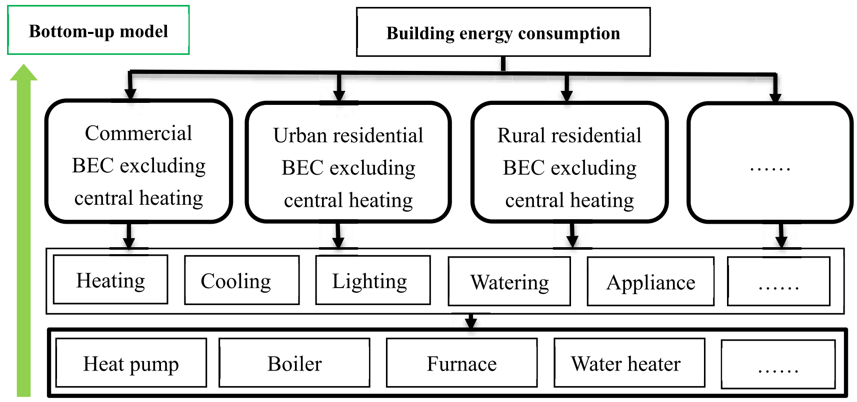

Fig. 6. TU-BERC's CBEM model structure.

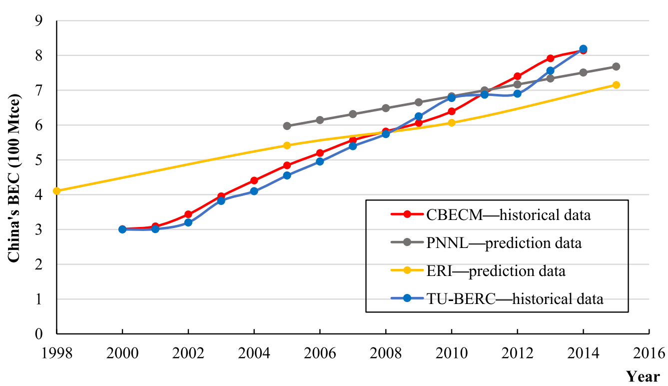

Fig. 7. Comparison of the results of this study and the results from TU-BERC, ERI and PNNL (Data source (Tsinghua University-Building Energy Research Center, 2014; Yu et al., 2014a; Zhou et al., 2003).

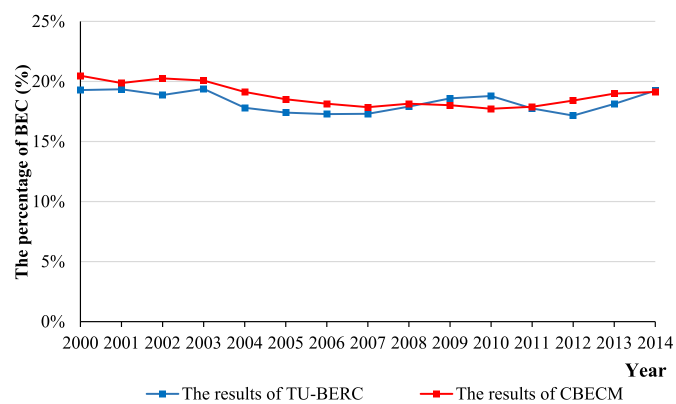

Fig. 8. Comparison of the BEC ratio to total energy consumption using CBECM and TU-BERC's method.

micro individual end-use service energy demand (Ecom et al., 2012; Yu et al., 2014a). Comparison of the BEC results of this study and the results from TU-BERC, ERI and PNNL are shown in Fig. 7.

Between 2000 and 2014, the BEC calculated with TU-BERC's CBEM model increased more than twice, with an average annual growth rate of 5.63%; while BEC data obtained using CBECM increased from 301 million tce to 814 million tce, a very similar average annual growth rate of 7.37%. ERI's data are the prediction data and 1998 is the base year data (Zhou et al., 2003), and PNNL's results are also the predicting data and base year is 2005 (Yu et al., 2014a). There are many assumptions for the base year data, so their data accuracy and quality are lower. From the ERI's prediction, before 2009, the BEC calculated with CBECM was higher than the figure for ERI, and it overtook the ERI figure on 2009. The growth rate of China's BEC of ERI figure was 4.0% annually, about half of the increase rate of CBECM result (7.4%) from 2000 to 2014. The growth rate of China's BEC of the PNNL data was much lower (1.8%) than the figure for CBECM. As a whole, the BEC results obtained from these institutes have consistent time series trend.

As for the percentage of the BEC out of total energy consumption, the data for the ERI and PNNL are the prediction data and the energy consumption they involved are final energy consumption. Therefore, it would be inaccurate to obtain the BEC ratio by dividing their results with the real total final energy consumption. So we just compare the BEC ratio out of total energy consumption using CBECM and TU-BERC's method, as shown in Fig. 8.

The two results also have similar linear relationship, with a correlation coefficient $R^2 = 0.9831$ that is quite close to 1. This indicates that the two results have a consistent time series trend.

From the comparison we can see, the modeling approaches of other institutes (i.e., TU-BERC, ERI and PNNL) are more complex and there are many parameter requirements and data assumptions. The generality of these kinds of methods is weak, and the value of their parameters are mostly obtained by simulating or estimating according to other exiting publications and experts' experience judgement. The calculation results can be greatly influenced by the difference between the data sources, the parameter assumptions and determining variables, and its accuracy needs to be further validated. In comparison, the CBECM proposed in this study is concise in its calculation and the data source is unified and authoritative. No parameter assumption is needed. The calculation result is general and robust, and it would not be affected by the difference of the measurement units.

5.2. Comparison with the results from IEA

The CBECM is actually proposed to split out the BEC from other sectors in the composition of *China Energy Statistical Yearbook* according to IEA's principles, so this section will present China's BEC results comparison using CBECM and IEA's methods. And the results comparison on China's BEC are shown in Fig. 9.

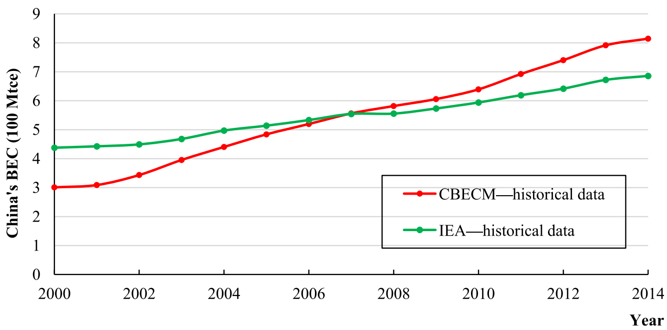

Fig. 9. Comparison of China's BEC using CBECM and IEA method (Data source (Birol et al., 2014):).

According to the results of IEA, as shown in Fig. 8, China's BEC increased from 438 Mtce to 686 Mtce during the period 2000–2014. Before 2007, the BEC calculated with CBECM was higher than the figure for IEA, and it overtook the IEA figure in 2007. The changing trends of the results of CBECM and IEA were consistent, with the growth rate of 3.3% and 7.6% respectively from 2000 to 2014. The difference for the absolute quantity of China's BEC between CBECM and IEA may be explained as follows: First, industry energy consumption is classified as "intermediate energy consumption" by the IEA system, while it is categorized as "industrial energy consumption" by the Chinese method. Second, in IEA's balance, biomass energy, solar energy, geothermal energy, and other non-commercial energy sources are also counted in residential energy consumption. Third, IEA uses the final energy consumption to calculate the BEC and CBECM uses the primary energy to calculate BEC.

From the comparison we know that IEA's method is not appropriate for Chinese policy makers to adopt. Energy consumption in China's energy statistics is divided according to the economic sector rather than the purpose of the energy use in IEA method. The cap and energy intensity goals of each region were set in the comprehensive work plan of in the 13th FYP for the energy saving and emission reduction released by the State Council. And they relied on the *China Statistical Yearbook*. CBECM is established in line with China's national conditions and it can show overwhelming advantages over other methods for the China's governmental officials to set BEE policy and evaluate the policy impact.

5.3. Comparison with the surveying results of the MOHURD

The CBECM proposed in this study can also be used to determine the upper and lower limits of the BEC at the provincial level and then to calibrate the reliability of the estimated or statistical data on BEC. China civil BEC statistical reporting system was implemented by MOHURD in 2008 and data were surveyed and reported from grass-roots units and hierarchically follow administrative orders to eventually reach MOHURD level rather than in a professional and standardized statistical method. It was carried out every two years. Statistics is a very specialized field of work, requiring training and experience. Few implementation personnel in the grassroots organizations have such training or the funds to get the training. In addition, there is little coordination between organizations and agencies. Currently, the open data from the MOHURD is limited and only the data in 2011 are available. In this section we will use the CBECM to calibrate the reliability of the MOHURD's data.

Table 3
Upper and lower limits of BEC in different regions in 2011 calculated with CBECM.

Regions	The lower limit of BEC		The upper limit of BEC	
	BEC (10 thousand tce)	percentage	BEC (10 thousand tce)	percentage
Beijing	2771.69	39.62%	5338.84	76.32%
Tianjin	1026.18	13.51%	2658.59	34.99%
Hebei	3326.03	11.28%	7970.08	27.02%
Shanxi	2238.35	12.22%	4956.73	27.06%
Inner Mongolia	3380.95	18.04%	6489.32	34.63%
Liaoning	2361.81	10.40%	7435.56	32.74%
Jilin	1437.11	15.79%	3530.28	38.78%
Heilongjiang	2150.27	17.74%	5297.91	43.72%
Shanghai	1850.20	16.42%	4069.36	36.11%
Jiangsu	2851.10	10.33%	6669.99	24.18%
Zhejiang	2929.77	16.43%	5694.32	31.94%
Anhui	1452.81	13.74%	2932.69	27.74%
Fujian	1603.58	15.05%	3174.64	29.80%
Jiangxi	913.96	13.19%	1875.75	27.07%
Shandong	4417.21	11.90%	11011.55	29.66%
Henan	2921.51	12.67%	6120.55	26.54%
Hubei	2450.66	14.78%	4955.67	29.89%
Hunan	2781.60	17.21%	4967.45	30.74%
Guangdong	5172.95	18.16%	9595.52	33.69%
Guangxi	1104.15	12.85%	2369.10	27.58%
Hainan	261.16	16.32%	523.68	32.72%
Chongqing	1034.99	11.77%	2205.12	25.08%
Sichuan	2502.75	12.71%	5652.41	28.70%
Guizhou	1524.60	16.81%	2720.95	30.01%
Yunnan	1059.85	11.11%	2395.46	25.11%
Shaanxi	1765.69	18.09%	3332.04	34.14%
Gansu	868.19	13.37%	1894.46	29.16%
Qinghai	380.50	11.93%	801.53	25.13%
Ningxia	307.23	7.12%	985.10	22.82%
Xinjiang	1149.69	11.58%	3050.99	30.73%

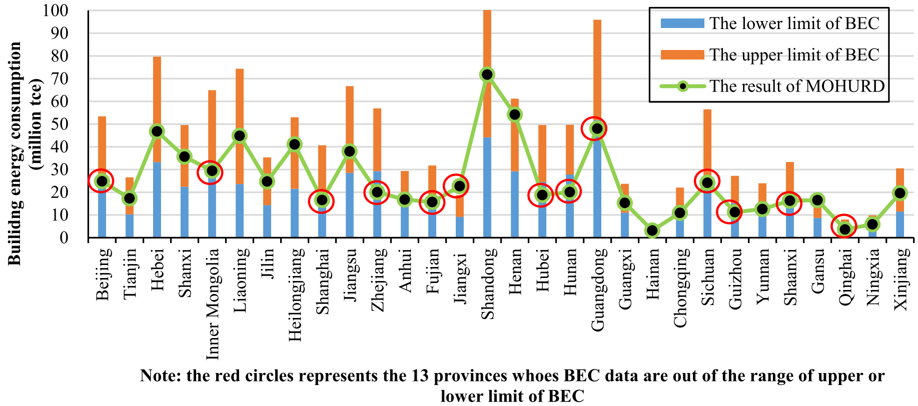

Fig. 10. Calibrate the BEC by region of the MOHURD data in 2011.

In *China Energy Statistical Yearbook—energy balance sheet* by region, only the physical quantity data of the energy consumption can be obtained. Therefore, the processing method for regional upper and lower limits of BEC calculated with CBECM is as follows. The energy consumption data of each kind of energy in regional energy balance sheets needs to be multiplied by the corresponding adjustment coefficient for conversion from a physical quantity to standard quantity. The adjustment coefficient is consistent with the coefficient at the national level, where the physical quantity and standard quantity can both be obtained. And the coefficient for the electricity consumption is according to the coal power plant equivalent method. The upper and lower limits of BEC of each region are calculated using (A-1) and (A-2), as shown in Table 3.

The calibration shows that (as shown in Fig. 10), data for 13 provinces calculated by the MOHURD are in excess of the upper or lower limit (which are shown in red circles). Regions outside the upper or lower limit include Beijing, Inner Mongolia, Shanghai, Zhejiang, Fujian, Jiangxi, Hubei, Hunan, Guangdong, Sichuan, Guizhou, Shaanxi and Qinghai. The results review reflects the need for the MOHURD to improve the quality of the provincial BEC data.

From the calibration we can see, the comprehensive energy intensity based method can facilitate to compare the building energy use in different regions and it can butt to butt with the China civil BEC statistical reporting system which was implemented by MOHURD. However, the basic data is hard to obtain and large-scale BEC statistical survey is needed to derive the reasonable average energy intensity. Besides, there is no authoritative open data for reference. In comparison, CBECM does not need the large-scale survey and it is easy to carry out. The authoritative data can be obtained from *Statistical Yearbook* and it is concise in calculation. The complete time-series data can be obtained easily which can facilitate to analyze the macro changing trend of China BEC.

6. Conclusion

Accurately measuring comprehensive and objective BEC data is critical to support policy impact evaluation and the carbon emission peak analysis. This study proposed China BEC calculation method (CBECM) based on the *Statistical Yearbook—energy balance sheet*. And then China's BEC from 2000 to 2014 were calculated using CBECM and the results were compared with other studies. The main conclusions are as follows:

(1) This study established a set of unified China building energy calculation method (CBECM) by splitting out the energy consumption related with buildings mixed in other sectors in *China Statistical Yearbook—energy balance sheet*. The core idea of this method includes: calculating the basic amount of BEC, deducting the transportation energy consumption contained in the basic amount, adding the corrected heating energy consumption, and adding the BEC contained in other remaining sectors.

(2) China's BEC were measured using the CBECM and results indicated that China BEC was 814 Mtce in 2014, accounting for 19.1% of total primary energy consumption. Of the China's BEC in 2014, commercial BEC accounted for the largest (40%), and percentage for urban and rural residential BEC were 37% and 23% respectively. From 2000 to 2014, China BEC increased 1.7 times, rising from approximately 301 to 814 million tce, while the BEC percentage of total energy consumption remained relatively stable between 17.7% and 20.3%.

(3) The results of China's BEC calculated with CBECM was compared with the results from other studies. The results of CBECM were similar to TU-BERC's results, while it differed significantly with other studies' results. The BEC changing trend was relatively consistent comparing results from this study and from other studies. The BEC data quality of the MOHURD through surveying needs to be improved.

The contributions and implications of this study are as follows. Firstly, it proposed a set of concise, practical and universal calculation method for China's BEC. The proposed method can overcome previous studies' different definitions of BEC, inconsistent total energy consumption, various conversion of electricity and complex assumptions etc. Secondly, this study calculated China's BEC by type from 2000 to 2014 using CBECM, which can provide reliable and valuable data evidence for the governmental officials in terms of building energy efficiency, energy planning or energy policy evaluation in the building sector. Thirdly, the CBECM and the results of this study were compared with other studies like TU-BERC, IEA, ERI, PNNL and China MOHURD. The CBECM is superior to other methods in the following aspects: data source is authoritative, data collection is convenient with easy-to-obtain time series data on BEC, calculation method is general and calculation process is concise etc. CBECM can provide a very concise and practical means of obtaining consistent China BEC data for government and local officials even if they have no statistical training in Chinese conditions. The results of CBECM have higher degree of recognition and the CBECM can be used to calibrate the statistical data at the

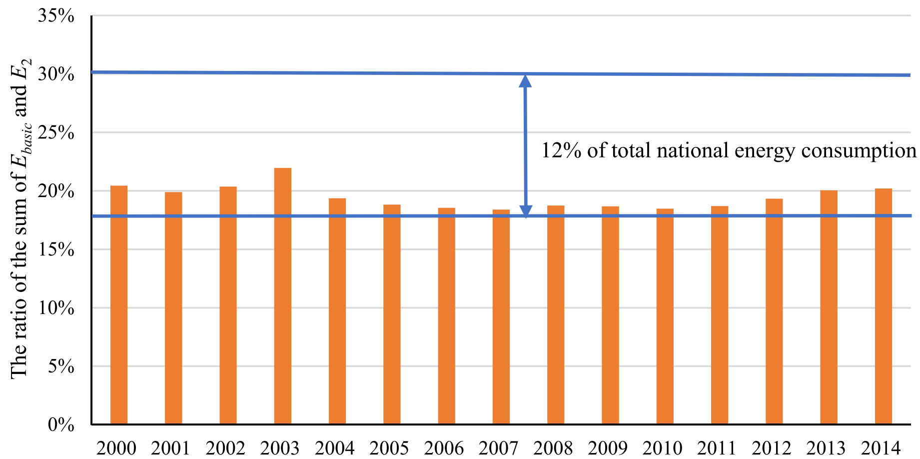

Fig. A1. The ratio of E_{basic} and E_2 of China's total energy consumption (2000–2014).

2) BEC lower limit checking method

provincial level reported by the MOHURD.

Future reform of the China BEC statistical system should align it with international standards. This study suggests that energy consumption statistics from residential buildings should be collected using household surveys. Another suggestion is to strengthen the quality control of statistical data and to develop a unified data processing and analysis tool.

Acknowledgments

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Appendix A. The upper and lower limit methods for checking

1) BEC upper limit method of checking

Among the many values of China BEC calculated by Chinese institutions or international institutions, the MOHURD's result is the largest percentage at 27.5%, less than 30%. This result didn't include biomass energy. We therefore set 30% to be the upper limit of China BEC: the basic amount of energy consumption (i.e., “Wholesale and retail trades, hotels and catering services”, “other sectors” and “household consumption”) plus the correction amount for heating energy consumption, plus an additional 12% of the total energy consumption (the upper limit of BEC = the basic amount of BEC + the correction amount for heating energy consumption + the amount of total energy consumption × 12%). The reason is, as analyzed in Section 3.2, some part of transportation energy consumption is contained in the basic BEC and this portion of energy consumption should be removed when calculating the BEC. In this study, instead of deducting this part of energy consumption, an additional 12% of the total energy consumption is added. This ensures that BEC will not exceed the value or, in other words, the resulting value is the upper limit of BEC

$$E_{upper} = E_{basic} + E_2 + E_{total} \times 12\% \tag{A-1}$$

whereE_{total} represents total primary energy consumption. The explanation for the 12% are as follows: most professionals in the construction industry at present think that their proportion of BEC will not exceed 30%. In formula (6), it is assumed that theE_{upper} equals $E_{basic} + E_2 + E_{Others(\max)}$, while actually, the percentage of the sum of $E_O$and E_2 on the total energy consumption (E_{total}) is more than 18%, as shown in Fig. A1. Therefore, $E_{Other(max)} \le E_{total} \times 12\%$. Therefore, $E_{upper} \le E_{basic} + E_2 + E_{total} \times 12\%$. Thus, the maximum of$E_{upper}$ should equal$E_{basic} + E_2 + E_{total} \times 12\%$.

“Wholesale and retail trades, hotels and catering services”, “other sectors” and “household consumption” are part of tertiary industry, and residential energy consumption as defined in the *Statistical Yearbook*. These three items (i.e., the basic amount of BEC) do not contain production energy consumption. What remains from deducting business and private transportation energy consumption all belongs to BEC. As with the analysis in section 3.3, part of the oil consumption contained in these three sectors should be deducted (Wang, 2007, 2006), plus the corrected amount of heating energy consumption and the BEC in other remaining sectors, when calculating BEC. Now, all the oil consumption contained in these three sectors will be deducted and even another two part of BEC will not be added; this is the lower limit of BEC, so the BEC that is calculated should not be less than this value. That is, the lower limit of BEC = the basic amount of BEC − all the oil consumption is the basic amount of BEC. The formula is

$$E_{lower} = E_{basic} - \left(E_W^t + E_O^t + E_H^t\right)^{all} \tag{A-2}$$

where $\left(E_W^t + E_O^t + E_H^t\right)^{all}$ means all of the oil consumption contained inE_W, E_O and E_H.

Table A1
The composition of *China Statistical Yearbook -Energy Balance Sheet* in 2014, Energy Balance of China (Standard Quantity) −2014, Unit:10 000 tec

Item	Energy Total		Coal Total	……	Petroleum Products Total	Crude Oil	Gasoline	Kerosene	Diesel Oil	……	Natural Gas	LNG	Heat	Electricity	Other Energy
	(coal equivalent calculation)	(calorific value calculation)													
Total Primary Energy Supply	**426094.60**	**400590.74**	**280908.72**	……	**73973.98**	**73636.67**	**−1852.73**	**−1095.58**	**−673.88**	……	**20711.60**	**3483.65**		**16831.47**	**5736.80**
Indigenous Production	361865.69	336149.38	266315.72	……	30204.78	30204.78				……	16920.41			16971.68	5736.80
Hydro Power	32901.21	13080.70		……						……				13080.70	
Nuclear Power	4097.07	1628.89		……						……				1628.89	
Wind Power	4824.75	1918.20		……						……				1918.20	
Import	76345.56	76219.86	17829.40	……	50693.31	44054.30	4.97	609.34	69.02	……	4130.36	3483.65		82.96	
Domestic Airplanes&Ships Refueling in Abroad	979.47	979.47		……	979.47			451.50	11.18	……					
Export (−)	7203.89	6865.74	483.98	……	4993.02	85.74	746.78	1569.25	598.10	……	339.17			223.16	
Oversea Airplanes&Ships Refueling in China	1066.89	1066.89		……	1066.89			572.87	19.50	……					
Stock Change	−4825.33	−4825.33	−2752.41	……	−1843.67	−536.65	−1110.92	−14.29	−136.49	……					
Input(−) & Output(+) of Transformation	**−2442.76**	**−81935.26**	**−200461.46**	**……**	**−2552.88**	**−72263.23**	**16228.16**	**4533.35**	**25640.69**	**……**	**−4565.73**	**466.68**	**12900.59**	**52461.70**	
Thermal Power		−79492.50	−121918.29	……	−329.28	−12.67	−0.06	−0.01	−37.64	……	−2966.47	−308.56	−1878.73	52461.70	−784.42
Heating Supply	−5036.10	−5036.10	−14342.83	……	−709.25	−9.93	−0.07	−0.03	−6.89	……	−676.39	−11.83	12761.92		−295.01
Coal Washing	−6527.41	−6527.41	−7405.23	……						……					
Coking	−2730.85	−2730.85	−55381.23	……						……					
Petroleum Refineries	8467.89	8467.89	−471.28	……	9068.11	−72240.63	16229.32	4533.40	25696.45	……	−60.71				
Petroleum Products Input (−)	−10582.46	−10582.46		……	−10582.46		−1.03		−11.23	……					
Gas Works	−230.56	−230.56	−662.24	……						……	−23.14				
Coke Input (−)	−48.54	−48.54		……						……					
Natural Gas Liquefaction	−51.95	−51.95		……						……	−839.02	787.07			
Briquettes	−280.37	−280.37	−280.37	……						……					
Recovery of Energy	14577.61	14577.61		……						……			2017.40		1079.43
Loss	**10200.97**	**4428.25**		**……**	**158.33**	**154.06**				**……**	**264.16**	**24.62**	**171.39**	**3809.75**	
Total Final Consumption	**413162.29**	**313935.03**	**80311.59**	**……**	**71198.55**	**1222.68**	**14383.79**	**3436.29**	**24955.78**	**……**	**15900.39**	**3934.72**	**12730.19**	**65485.80**	**5736.94**
Agriculture, Forestry, Animal Husbandry and Fishery	8094.27	6207.09	1928.39	……	2507.70		318.71	1.10	2173.97	……	10.28		3.03	1245.46	478.38
Industry	283419.55	213207.82	64420.63	……	21906.51	1222.68	718.41	25.50	2268.72	……	8058.18	3531.97	9121.57	46336.78	1676.12
Non-Energy Use	21425.29	21425.29	6245.64	……	10847.39	518.62	15.23	2.91	40.04	……	1581.01	326.71			
Construction	7519.59	6175.67	703.60	……	4488.55		487.08	15.32	804.25	……	24.45		27.76	886.93	34.95
Transport, Storage and Post	35959.53	33986.97	389.53	……	28491.80		6864.09	3260.67	16090.46	……	2210.84	402.75	82.12	1301.81	1105.52
Wholesale, Retail Trade and Hotel, Restaurants	10873.01	7156.72	2905.24	……	845.73		320.46	16.60	335.31	……	606.10		195.41	2452.59	88.11
Others	20084.01	13352.05	3082.99	……	4638.38		2557.39	74.65	1848.69	……	537.03		351.25	4442.81	278.85
Residential Consumption	47212.33	33848.70	6881.21	……	8319.88		3117.64	42.45	1434.37	……	4453.50		2949.05	8819.43	2075.01
Urban	26946.49	19622.03	1022.88	……	5818.29		2158.15	5.53	803.62	……	4437.06		2949.05	4833.83	231.05
Rural	20265.84	14226.67	5858.33	……	2501.59		959.49	36.92	630.75	……	16.44			3985.60	1843.96
Statistical Difference	**288.58**	**292.19**	**135.67**	**……**	**64.22**	**−3.30**	**−8.35**	**1.49**	**11.03**	**……**	**−18.68**	**−9.01**	**−0.99**	**−2.38**	**−0.14**
Total Energy Consumption	**425806.02**	**400298.55**													

Notes: in Table A1, some kinds of energy form are omitted due to the limited space.

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